Colorado Bioenergy Resources

All plant or plant-derived material—"biomass"—from trees and grasses, agricultural crops, agricultural or forestry residues, and waste materials from plant products can be used to produce "bioenergy." For heating applications or electricity generation, biomass can be burned in its solid form, or first converted into liquid or gaseous fuels for energy sources. Biomass power technologies convert renewable biomass fuels into heat and electricity using modern boilers, gasifiers, turbines, generators, fuel cells, and other methods. For transportation use, liquid fuels made from biomass (biofuels), fill the bill best. The two most common biofuels used in the United States today are ethanol and biodiesel. While they can each be used as alternative fuels, both are more frequently used as additives to conventional fuels to reduce toxic air emissions and improve performance.

Biomass Resources

Biomass materials that are byproducts from activities such as wood products manufacturing, construction, agriculture, and forest harvesting or management are referred to as "residues." Residues can be inexpensive and clean sources of biomass. Using biomass residues as a fuel can avoid fossil-fuel purchases while reducing the costs and environmental impacts of disposal. In the future, fast growing grasses, shrubs, and trees (also referred to as "energy crops") could be grown specifically for use as fuels to meet a growing demand for sustainable electricity and transportation fuels. Studies indicate that Colorado has a fair biomass resource potential. Biomass resource supply figures discussed below are based on estimates for five general categories of biomass: urban residues, mill residues, forest residues, agricultural residues, and energy crops. Of these potential biomass supplies and the quantities cited below, most forest residues, agricultural residues, and energy crops are not presently economic for energy use due to collection/transportation issues or lack or production (energy crops). New tax credits or incentives, increased monetary valuation of environmental benefits, or sustained high prices for fossil fuels could make these fuel sources more economic in the future. The data on biomass potential for Colorado (and other states in the U.S.) were obtained from Oak Ridge National Laboratory[1] and are reported in US standard dry tons (2000 lb).

Wood is the most commonly used biomass fuel for heat and power. The most economic sources of wood fuels are usually urban residues and mill residues. **Urban residues** used for power generation consist mainly of chips and grindings of clean, non-hazardous wood from construction activities, woody yard and right-of-way trimmings, and discarded wood products such as waste pallets and crates. Local governments can encourage segregation of clean wood from other forms of municipal waste to help ensure its re-use for mulch, energy, and other markets. Using clean and segregated biomass materials for electricity generation recovers their energy value while avoiding landfill disposal. **Mill residues**, such as sawdust, bark, and wood scraps from paper, lumber, and furniture manufacturing operations are typically very clean and can be used as fuel by a wide range of biomass energy systems. The estimated supplies of urban and mill residues available for energy uses in Colorado are 158,000 and 180,000 dry tons per year, respectively.

Forest residues include underutilized logging residues, imperfect commercial trees, dead wood, and other non-commercial trees that need to be thinned from crowded, unhealthy, fire-prone forests. Because of their sparseness and remote location, these residues are usually more expensive to recover than urban and mill residues. The estimated supply of forest residues for Colorado is 720,000 dry tons per year.

Agricultural residues are the biomass materials remaining after harvesting agricultural crops. These residues include wheat straw, corn stover (leaves, stalks, and cobs), orchard trimmings, rice straw and husks, and bagasse (sugar cane residue). Due to the high costs for recovering most agricultural residues, they are not yet widely used for energy purposes; however, they can offer a sizeable biomass resource if supply infrastructures are developed to economically recover and deliver them to energy facilities. An estimated 2,524,000 dry tons per year is available from corn stover (90%) and wheat straw (10%) in Colorado.

Energy crops are crops developed and grown specifically for fuel. These crops are carefully selected to be fast growing, drought and pest resistant, and readily harvested alternative crops. Energy crops include fast-growing trees, shrubs, and grasses such as hybrid poplars, hybrid willows, and switchgrass, respectively. In addition to environmental benefits, energy crops can provide income benefits for farmers and rural landowners. For Colorado, the production potential for energy crops has not been estimated.

Bioenergy Technologies

Some bioenergy technologies are commercially available, such as combustion and wet and dry mill technology for ethanol. In addition, the biomass research community is developing advanced technologies. The National Renewable Energy Laboratory in Golden performs research and development for DOE's Office of the Biomass Program with the goal of making the various technologies for biomass conversion to power, fuels and chemicals technically and economically viable. Several companies from the power, ethanol, chemical and agricultural sectors are working with the Biomass program and NREL to advance these technologies.

Biomass power can be produced using different processes. Combustion is one option for generating power from biomass resources; gasification is another. When biomass is heated with no oxygen or only about one-third the oxygen needed for efficient combustion, it gasifies to a mixture of carbon monoxide and hydrogen-synthesis gas or syngas. Combustion is a function of the mixture of oxygen with the hydrocarbon fuel. Gaseous fuels mix with oxygen more easily than liquid fuels, which in turn mix more easily than solid fuels. Syngas therefore inherently burns more efficiently and cleanly than the solid biomass from which it was made. Gasification can thus improve the efficiency of large-scale biomass power facilities. Like natural gas, syngas can also be burned in gas turbines, a more efficient electrical generation technology than steam boilers to which solid biomass and fossil fuels are limited.

An estimated 5.2 billion kWh of electricity could be generated using the renewable biomass fuels in Colorado (3,582,000 tons total) in a biomass integrated gasification combined cycle system (BIGCC). This is enough electricity to fully supply the annual needs of 612,000 homes, or 37 percent of the 2001 residential electricity use in Colorado[2].

Corn ethanol production in the US was almost 3 billion gallons in 2003[3]. In general, current U.S. ethanol production is based largely on the starch in kernels of field corn, the nation's largest agricultural crop. (The predominant use of field corn is for animal feed. Current ethanol production uses only about 7% of the crop.) Any starch or sugar crop, however, can now be used to make ethanol. Dry grind mills, the most common facilities built today, cost about $1.25 to $1.35 per annual gallon to build, or $50 to $54 million for a 40 million gallon plant. Operating costs of about $1.19 per gallon are dominated by the corn cost[4]. Besides the ethanol product, Distillers Dried Grain (DDG), a solid co-product containing about 30% protein, is sold as an animal feed component. Corn ethanol plants emit volatile organic compounds (VOC), which can be thermally oxidized, and CO_2, which can be another co-product if the local market exists.

Although corn ethanol plants are designed to be zero water discharge, most plants have a water discharge permit. An optimal plant site minimizes corn and ethanol transportation distances.

In 2003, Colorado produced 120 million bushels (3,360,000 tons) of corn[5]. An estimated 324 million gallons of ethanol could be produced from this. Using 7% of the corn would result in 23 million gallons of ethanol. At a plant capacity of 40 million annual gallons, up to 8 plants could be built in Colorado to utilize its current corn production. Currently, Coors Brewery in Golden produces about 1.5 million gallons of ethanol annually from spent beer. The state's first ethanol plant, producing 56 million gallons per year, is scheduled to be in production by the middle of 2005 on 35 acres outside Greeley. Ninety million gallons are consumed in Colorado each year.

Non-starch ethanol will add to the production. As commercialization of advanced technology makes it possible to produce ethanol from biomass other than starch and sugar, vast additional resources will become available to supplement ethanol production from corn kernels. The first advanced ethanol technology plants will likely use "opportunity" feedstocks such as paper mill or food processing wastes that are from concentrated sources and now have low value or must be disposed. In the intermediate future, ethanol can be made from agricultural residues such as corn stover (stalks and husks—roughly equivalent in mass to the corn grain crop), or forestry residues such as from lumber mills or from forest thinning to reduce fire danger near urban areas. In the long term, ethanol could be made from dedicated energy crops of fast-growing trees and grasses such as poplars and switchgrass.)

An estimated 280 million gallons of ethanol could be produced from Colorado's combined non-starch biomass resources using an enzymatic hydrolysis process. The majority, 200 million gallons, would be from the collectible corn stover. At a plant capacity of 40 million annual gallons, up to 7 plants could be built. The capital cost for a plant producing ethanol from non-starch biomass is higher due to the more interlinked nature of the feedstock. Operating costs will be similar but the feedstock price is expected to be lower than corn. Possible co-products include chemicals from the lignin portion of the feedstock.

Biodiesel production is based largely on oil from soybeans and recycled restaurant cooking oils. Both of these are currently in surplus and biodiesel production uses only a minor fraction of available supply. Any animal fat or vegetable oil, however, can be used to make biodiesel. U.S. biodiesel sales in 2003 were 25 million gallons[6]. Colorado produced 179,000 bushels of soybeans in 2002[7]. An estimated 250,000 gallons of biodiesel could be produced from this.

Methanol, hydrogen and other fuels can also be made from biomass. Just as syngas mixes more readily with oxygen for combustion, it also mixes more readily with chemical catalysts than solid fuels do, greatly enhancing its ability to be converted to other valuable fuels, chemicals and materials. The Fischer-Tropsch process converts syngas to liquid fuels needed for transportation. The water-gas shift process converts syngas to more concentrated hydrogen for fuel cells. A variety of other catalytic processes can turn syngas into chemicals or other products. Using an estimated hydrogen yield of 66 kg per dry ton for wood[8], the 1,058,000 tons of total wood residues (urban, mill and forest) in Colorado could produce 70 million kilograms of hydrogen.

Additional Biomass Resource and Bioenergy Technology Information
Much of the text for this paper was taken directly from the Colorado Bioenergy Resources web site. For more information about biomass feedstocks, go to the Bioenergy Feedstock Development Program home page or for uses in the United States, visit the Biomass Program home page or NREL's biomass program home page.

[1]Biomass Feedstock Availability in the United States: 1999 State-Level Analysis Marie E. Walsh, et. al., Oak Ridge National Laboratory, Oak Ridge, TN, April 30, 1999, Updated January, 2000. http://bioenergy.ornl.gov/resourcedata/index.html

[2] Colorado Energy Efficiency and Energy Consumption data:
http://www.co.larimer.co.us/compass/electricity_env_use.htm
http://www.swenergy.org/factsheets/COfactsheet.pdf

[3] Renewable Fuels Association: http://www.ethanolrfa.org/outlook2004.html

[4] Ethanol Plant Development Handbook, 4th edition, BBI International, http://www.bbiethanol.com/

[5] Colorado Corn Production for 2003: http://www.ncga.com/WorldOfCorn/main/productionData.htm

[6] National Biodiesel Board sales volume estimate for 2003. http://www.biodiesel.org/resources/faqs/

[7] Colorado oilseed crops by acres harvested. http://www.nass.usda.gov/co/

[8] Using a mass yield of hydrogen from biomass of 7.2%. Personal communication, Margaret Mann, NREL Hydrogen, Fuel Cells & Infrastructure Technologies Program.